

VOLUME 79

SEPARATE No. 181

PROCEEDINGS

AMERICAN SOCIETY
OF
CIVIL ENGINEERS

APRIL, 1953



SLACKWATER IMPROVEMENT OF THE COLUMBIA RIVER

By O. E. Walsh

WATERWAYS DIVISION

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Printed in the United States of America*

Headquarters of the Society
33 W. 39th St.
New York 18, N.Y.

PRICE \$0.50 PER COPY

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Published at Prince and Lemon Streets, Lancaster, Pa., by the American Society of Civil Engineers. Editorial and General Offices at 33 West Thirty-ninth Street, New York 18, N. Y. Reprints from this publication may be made on condition that the full title of paper, name of author, page reference, and date of publication by the Society are given.

AMERICAN SOCIETY OF CIVIL ENGINEERS

Founded November 5, 1852

PAPERS

SLACKWATER IMPROVEMENT OF THE
COLUMBIA RIVER

BY O. E. WALSH¹

SYNOPSIS

Navigation on the Columbia River and its tributaries is vital to the economy of the Columbia River basin. This paper presents a description and history of the basin and describes the effects of the many slackwater improvement projects in this area.

It is concluded that great economic benefits are yielded by navigational improvements in this basin, and that coordination with other water uses and with other forms of transportation is feasible.

INTRODUCTION

Rivers were the highways for the pioneers and, as such, they played an important part in the early settlement of many regions. However, other forms of transportation developed, along with the development of the tributary area, and many rivers lost their stature as important arteries of commerce and were forced to adopt new roles in the economy of their regions. No great river ever remained an unimportant resource for long, but in many instances it has taken centuries for the full worth of a river to be realized and for its full potential to be developed. The Columbia River, long recognized as one of the great rivers of the west, has only in recent years started its climb into a place of national importance as one of the great rivers of the world. Attention is focussed (1953) on the Columbia River because of its tremendous hydroelectric power potential, since in the Columbia River and its tributaries are concentrated approximately one third the potential water power of the United States. In a period of industrial expansion—in which there is an ever growing need for greater supplies of economical electrical energy—the vast resources of the Columbia River can be tapped for the benefit of the nation and, thus, the

NOTE.—Written comments are invited for publication; the last discussion should be submitted by October 1, 1953.

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world. Although much has been said about Columbia River power, and much more can and will be said about this great resource, this paper is devoted to another phase of the Columbia River development which has guided, and will continue to guide, the economic growth of the region. Navigation has been an important function of the Columbia River since the day Capt. Robert Gray sailed his ship, *The Columbia*, into its mouth in 1792. It truly served as a highway for the pioneer settlers, even though it was a rough one in many spots. Although the commerce of the lower river has continued to grow for more than 150 years, those "rough spots" in the upper river highway have retarded the growth of river commerce above tidewater since the hardy days of iron men and wooden ships. It has been only through the use of equipment of better design and as a result of continued improvements around and through these spots of turbulent white water that river commerce has remained in active competition with the paralleling railroads and highways and has grown remarkably. For the swift and rugged Columbia River and for the principal tributary, the Snake River, adequate navigation can be provided only by slackwater improvement similar to that of the great tonnage carrier, the Ohio River.

DESCRIPTION OF BASIN

To understand the problems and potentialities of Columbia River navigation better, the geography and economic development of the region should first be examined and also its navigation history. The Columbia River, with its tributaries, drains an area of 259,000 sq miles on the Pacific slope of the North American continent, mostly between the Rocky Mountains and the Cascade Range. In the part that is of maximum length the basin extends north of the international boundary 270 miles into Canada and south into the United States approximately 550 miles. The widest part of the basin is from the mouth of the Columbia River at Astoria, Ore., to the headwaters of the Snake River in Yellowstone Park in western Wyoming, a distance of 730



FIG. 1.—PART OF COLUMBIA RIVER BASIN

miles. Fig. 1 shows that the 219,500 sq miles of the basin in the United States includes most of Idaho, the greater parts of Washington and Oregon, all of Montana west of the continental divide, and small areas of Wyoming, Nevada, and Utah. The basin boundaries are mostly mountain ranges, which comprise a large percentage of the basin area.

The Columbia River has its source in Columbia Lake in the Rocky Mountains of Canada, and flows a distance of 462 miles through British Columbia before crossing the international boundary at the northeast corner of the State of Washington. In the United States, it flows generally south through the central part of Washington to a junction with the Snake River and then turns westerly to the Pacific Ocean, a total distance of 1,207 miles from its source in Columbia Lake. The total fall of the river from its source to the ocean is 2,652 ft. The Snake River contributes slightly more than one fifth of the 180,000,000 acre-ft of mean annual runoff of the Columbia basin and drains 109,000 sq miles. The Snake River falls a distance of 9,000 ft in the 1,070 miles from its headwaters to a junction with the Columbia River near Pasco, Wash.

The climate of the Columbia basin varies between the mild coastal conditions at the mouth of the river, to the dry semidesert climate of the inland valleys and plains, and between the extremes of temperature and precipitation found in the mountain altitudes. Annual precipitation ranges from 7 in. per yr to 150 in. per yr. Seasonal high water, usually a maximum in May or June, is caused by a rapid melting of the accumulated snow pack from the previous winter, and is often accelerated by the melting action of late spring rains. Winter runoff is frequently extremely low because of freezing weather which occasionally extends to the lower reaches of the river west of the Cascade Mountain Range. The discharge of the Columbia River varies from the mean annual of about 200,000 cu ft per sec, to an upper limit of 1,240,000 cu ft per sec attained at The Dalles, Wash., during the maximum flood of record in 1894, and downward to a lower limit of only 36,000 cu ft per sec at the same point during the freeze-up of January, 1937. The mean annual runoff is approximately 13 in. over the watershed area at the mouth, and a little more than 11 in. at The Dalles.

The population of the Columbia River basin was approximately 3,000,000 in 1950. Half the population is rural, about equally divided between farmers and nonfarmers. Its distribution is characteristically that of an immature, rapidly growing region. Concentrations are small, occurring in conjunction with the conversion of near-by natural resources. The only two large cities within the basin—Portland, Ore., with a population of 371,011 in 1950 or 24.6% of the population of the State of Oregon, and Spokane, Wash., with a population of 160,484. The population of the Columbia basin increased 28.3% between 1940 and 1950 or at twice the rate of the nation; and the population forecasts indicate a substantially greater growth in the future than for the United States as a whole.

The most important natural resources of the Columbia River basin are its agricultural land, forests, mineral deposits, fish, and, of course, its water resources. In direct relation to these resources, the most important industries are agriculture, lumbering, and mining. Since 1940 the availability of hydroelectric power, the development of new processing techniques, and the impetus of war-expanded markets have greatly accelerated the growth of manufacturing in the basin. Although timber products continue to lead in importance—more than 300,000,000,000 board ft, log scale, of timber exist in the United States

section of the basin, yielding more than one third the nation's total lumber production, and there is a sound policy of harvesting on a perpetual yield basis—electrochemical and electrometallurgical plants have been continuously attracted to the region because of the economical power rate, and have threatened to change the manufacturing picture. Aluminum reduction plants lead the light metals activity, and a titanium industry now (1953) is directing its attention to the region's great power potential. Although the basin produced 41% of the primary aluminum supply of the nation in 1945, growth since that time has been small, and further large expansion of all such industries must await an increased power supply. The exportation of raw material and partly processed commodities, and the importation of manufactured goods, characterize the trade of the region. The trend and aim of the region are to carry on the processing of local materials to the end product, thus greatly extending its industrial foundation and expanding its economy. The principal exports are lumber, wheat, orchard fruits, flour, refined and unrefined metals and mineral products, manufactured wood products and wood pulp, and canned salmon and tuna. The chief imports are petroleum and related products, steel, iron, and manufactured consumer goods.

Great distances and topographic barriers, not only between centers of population outside the basin but also between points within the basin, have made transportation facilities of vital importance to the development of the region. Many areas remain isolated and undeveloped because of the lack of adequate transportation facilities. This is particularly true of the area above Lewiston, Idaho, in the Snake River Canyon. Although the basin is served by six transcontinental railways, by numerous federal and state highways, and by many secondary roads, the water highway of the Columbia River still remains an important artery of commerce and, as it is canalized, becomes of increasing importance to more and larger portions of the basin.

In the pioneer settlement days, the Columbia River and its tributaries provided the principal means of transportation, and many streams were extensively traveled by water and by portage. With the coming of roads, railroads, and later, improved highways, navigation lost some of its importance on most of the Columbia River tributaries. Navigation by ocean-going vessels having as much as a 35-ft draft is possible between the mouth of the Columbia River and Vancouver, Wash.—a distance of 105 miles. The lower 12 miles of the Willamette River, from its confluence with the Columbia to Portland, also is navigable by ships of this size. This provides a total distance of 112 miles from the ocean to the head of deep-water navigation. Portland, Vancouver, and the lower Columbia River ports have grown tremendously because they are ports and handle water-borne commerce, and continued growth in this water commerce is indicated for the future. Shallow draft navigation is important on the Willamette River above Portland and on the Columbia River to Pasco and Kennewick, Wash., at the mouth of the Snake River, 328 miles, by river, from the mouth. Navigation on the Snake River to Lewiston, an additional 140 miles inland, now constitutes a potential more than a recognized commerce, because of the swift water, the inadequate depths, and the attendant hazards of the unimproved Snake River. However, small,

high-powered launches operate 92 miles upstream from Lewiston to serve the few isolated inhabitants of the Snake River Canyon and, for many of them, provide the only means of ready access to the outside world. Little river traffic has ever developed on the Columbia River above Kennewick, although the river is navigable for an additional 65 miles to the foot of the Priest Rapids.

HISTORY OF COLUMBIA RIVER NAVIGATION

The history of navigation in the tidal reaches of the lower Columbia and Willamette rivers has paralleled the history of the region. Under John McLaughlin, the Hudson Bay Company's fur-trading post at Vancouver was the economic and social center of the vast Oregon country until about 1845, and nearly all transportation was by water. Canoes, flatboats, and other small craft traveled the tributary streams and sailing ships came into Vancouver with supplies to exchange for furs. The furs were carried to China and converted to goods for the European trade. The first steamship on the Pacific was *The Beaver*, constructed in England and sent to Vancouver for the fur trade. By the 1830's, settlements in the Oregon country were producing exportable surpluses of the same commodities that still make up a large part of the present exports—namely, grain and lumber; and clipper ships rounded Cape Horn to carry these products to world markets. By 1870, following the dredging of a bar on the lower Willamette River—the first federal navigation project in the region—Portland became the commercial center of the area. Improvement of the entrance to the Columbia River was authorized in 1877 and progressively deeper river channels were authorized in 1902, 1912, and 1930. The present project, adopted in 1930, provides for a river channel 500 ft wide and 35 ft deep, extending from the mouth to Portland and Vancouver. A depth of 40 ft over the bar has been maintained since 1918 and the feasibility of deepening the entrance channel to 48 ft is now under study at the request of shipping interests. Commerce, conducted by deep-draft vessels, on the lower Columbia River has grown from modest fur shipments in the early settlement days from 430,586 tons in 1909, the start of reliable commercial statistics, to more than 9,500,000 tons in 1949. Commerce, conducted by shallow-draft vessels, on the river amounted to nearly 9,000,000 tons in 1949, composed primarily of log rafts and barge tows. In 1945, Portland reached eleventh place in tonnage among the ports of the United States, and second among the seaports of the Pacific Coast for ocean and local commerce combined. In this tidal reach of the river, navigation is both practical and economical, and its continued growth can be expected with the growth of the region and the development of the contributary upper Columbia River area.

The upper Columbia River and its logical navigation extension up Snake River has a different and more troubled history. The first record of travel on these streams comes from the report of the Lewis and Clark expedition of 1804–1805. Coming over the continental divide between the Missouri River basin and the Salmon River, the Lewis and Clark expedition proceeded north into the Bitterroot Valley. While crossing this valley to the Clearwater River, they built boats and followed the Clearwater, Snake, and Columbia rivers to the Pacific Ocean. The Snake River once was called the "Lewis

Fork" of the Columbia River, and as the third largest Columbia tributary is still called the "Clark Fork." Subsequent to the adventures of Lewis and Clark, trappers and pioneer settlers blazed a transportation route known as the Oregon Trail. This famous route, used by the early emigrants to the great Oregon country, essentially followed the Snake and Columbia rivers, except in the lower Snake River Canyon below Fort Boise and at the Cascade Gorge of the Columbia River, just above its principal terminus at Fort Vancouver. River commerce by light-draft vessel and portage developed and prospered until 1882, when completion of a railroad paralleling the south bank of the Columbia River from Wallula, Wash., near the mouth of the Snake River, to Portland interposed serious competition. Shortly afterwards regular river service was abandoned. Various attempts were made later to revive navigation in the upper river, but the difficulties of navigating the swift and treacherous river could not be overcome with profit to the operations in the face of the rate-cutting competition of railroads.

In almost 50 years of upper river navigation during the pioneer period, before the coming of railroads, many tons of freight and thousands of passengers were hauled through the white water of the Columbia and Snake rivers or portaged over its worst falls at the Cascade Rapids and Celilo, Wash. In the upper section of the Columbia River from the mouth of the Snake River to Celilo, the river flows in a series of pools and rapids. Within this 124-mile distance, there is a fall of 185 ft, 86 ft of which is concentrated in sixteen rapids having an aggregate length of 19 miles. The river slope at low water in these rapids, or natural dams, is from 3 ft per mile to 8 ft per mile, and in the slackwater reaches between the rapids, the slope averages less than 1 ft per mile. In the stretch between the upper and middle sections of the river, a distance of 12 miles, there is a fall of 81 ft at low water, primarily concentrated at Celilo Falls. There was a drop at low water of only 4 ft in the 43-mile middle stretch past The Dalles to the head of Cascade Rapids. Before the days of Bonneville Dam, the river had a fall of 37 ft in a distance of 7 miles between its middle and lower sections, in a reach that terminated at the head of tide at Warrendale, Ore., a short distance below the site of Bonneville Dam. Of this 37-ft drop, 25 ft were concentrated in a distance of 3,000 ft through the Cascade Rapids proper. The Columbia River, in this narrow gorge section, cuts directly across the heavily timbered Cascade Mountain Range. The narrow gorge, with precipitous slopes and cliffs that rise in many places to more than 3,000 ft above the river channel, turned most of the early pioneers southward to a safer passage for their wagons and possessions over the mountains—a much longer passage that was filled with the difficulties and hazards of high mountain passes.

In pioneer days, boats traveled in these three main sections of the Columbia River but seldom passed the separating Cascade Rapids or Celilo Falls sections. The first portages around Cascade Rapids, between the tidal section and The Dalles pool, were made by wagons. In 1859 a tramway was built and later steam portage railways were built on both sides of the river. Construction of the Cascade Lock and Cascade Canal was started in 1878, but these structures were not opened to traffic until November, 1896. Because of the obstructions

to navigation between the foot of Three Mile Rapids (about 1½ miles above the town of The Dalles) and Celilo, the head of navigation was at The Dalles, and freight and passengers were transferred by means of wagons over a wagon road between The Dalles and Celilo. A portage railroad was completed in about 1862, following the Oregon bank of the river to the town of Celile, about 1 mile above Celilo Falls, where freight was transferred to boats. In 1882, this portage railroad became a part of the main line of the railroad between Portland and Wallula (later the Union Pacific Railroad). Because of gold discoveries on the Salmon River in Idaho in 1862, the following few years witnessed the greatest era of steamboat activity on the river above Celilo. In 1864 steamers carried 36,000 passengers to and from the Idaho mining regions on the Salmon and Clearwater rivers. The boats ran regularly as far as Lewiston and frequently trips were made up the Clearwater River and up the Snake River above Lewiston. Navigation rapidly declined between 1866 and 1870, and during high-water periods most of the boats were taken to lower river points. In 1882 navigation above Celilo Falls almost ceased.

Between 1891 and 1894 and again from 1905 to 1910, active efforts were made to revive upper river navigation. The Dalles-Celilo Canal was opened to traffic in May, 1915, and another attempt was made to revive navigation on the river above Celilo. However, it was unsuccessful because of lack of patronage, and boat operations were discontinued in 1917. The failure of upper river navigation in these periods can be charged primarily to lack of control over railroad rates. The absence of the stipulation of fixed rates by state and interstate commissions made it possible for the railroads to reduce rates at will for a time sufficient to force boats from the river, whenever a steamboat company attempted to establish service. During the period from 1926 to 1930, no freight traffic passed through The Dalles-Celilo Canal. Although there were some experimental shipments in 1931, regular traffic was not revived until 1932, when a total movement of 408 tons passed through the canal, and tonnage has increased rapidly since that time. This increase is indicated by Fig. 2, which also shows a projected straight-line curve for commerce after 1950. The horizontal line designated "50-year average" is the estimated average tonnage for a 50-year period immediately following completion of the through waterway, and is set at 4,828,000 tons. With the authorization of the Bonneville Lock and Dam in 1933, a slackwater development program was initiated on the upper Columbia River. This program revived navigation on the upper river to a full-scale commercial operation.

SLACKWATER IMPROVEMENT

In the year before the Bonneville Dam Lock was opened, the traffic through The Dalles-Celilo Canal totaled 5,626 tons, representing primarily a new navigation venture in the upstream barge movement of petroleum products. In 1938, the year Bonneville Lock was opened, the tonnage quickly multiplied nearly eight times to a total of 44,349 tons. In 1939 it tripled, and nearly tripled again in 1940 with a tonnage of 325,900, before it leveled out for a more gradual increase. In 1949, traffic through The Dalles-Celilo Canal totaled 900,246 tons, probably more tons of commerce than had passed over the

upper river in its entire history prior to and including 1940. There are many reasons for this increase in navigation on the upper river, one of which is the Bonneville Lock and the slackwater now available to the entrance of The Dalles-Celilo Canal, which completely eliminated the navigation hazards of past years in the Columbia Gorge stretch of the lower river. The Cascade Lock walls extending above the normal Bonneville pool of El. 72 ft, still remain as a visible memento of early days.

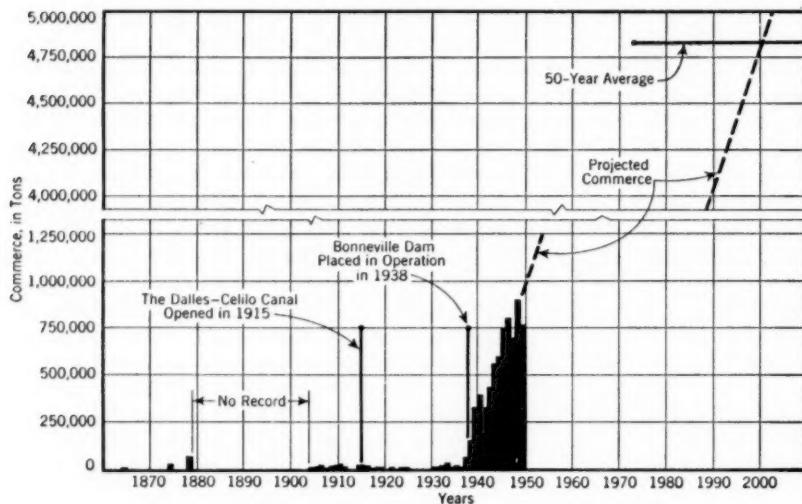


FIG. 2.—COMMERCE THROUGH THE DALLES-CELILO CANAL SECTION OF THE COLUMBIA RIVER

Bonneville Dam, located at the head of tidewater, 145 miles upstream from the ocean and 42 miles east of Portland, is the project farthest downstream of a series of locks and dams planned for construction on the Columbia and Snake rivers. (See Fig. 3.) A site in the Bonneville Dam vicinity was proposed by the Corps of Engineers, United States Army, in its Columbia River "308" Report² of 1932, as a part of a long range plan to develop fully the power potential of the Columbia River. The dam was started in 1933 as a Federal Emergency Administration project, was authorized by Congress in 1935 as a federal navigation project, and was placed in operation with two power units in 1938. Although the original 86,400 kw of installed capacity was considered far beyond the immediate needs of the region, additional units were found to be in demand immediately and, between 1938 and 1943, eight additional 54,000-kw generating units were added to complete the project. The phenomenal growth of the power load was no greater a surprise than the phenomenal navigation growth. The navigation lock at Bonneville was constructed to lift coastal steamers the 59 ft to the normal

² "Columbia River and Minor Tributaries," House Document 103, 73rd Congress, 1st Session (2 volumes), U. S. Govt. Printing Office, Washington, D. C., June 30, 1932.

pool level of 72 ft above mean sea level. The pool, which extends upstream about 48 miles to the foot of The Dalles-Celilo Canal, affords a navigable channel with depths of 30 ft or more from the dam to The Dalles. To complete the ship channel connection between The Dalles and the ocean, a channel 27 ft deep and 300 ft wide was authorized from Vancouver to The Dalles and, although excavation was started on the open channel work involved, work was stopped by World War II. The part of the channel between Vancouver and Bonneville was completed in 1949 and the remainder has been held in abeyance, awaiting a greater need for such a channel. Above Celilo, a channel 7 ft deep and 150 ft wide was authorized, to extend as far as Wallula, and a channel of no specific depth and width thence upstream to Kennewick. This improvement, to be obtained by the removal of rock pinnacles and shoals, has been essentially completed simultaneously with the ever growing river traffic. Similar open river improvements were also made on the Snake River from its mouth to above Lewiston, but a minimum controlling depth of less than 1 ft to Lewiston limited navigation to favorable river stages and prevented the Columbia River growth from extending up the Snake River.

Commercial navigation on the Columbia River above Vancouver is conducted principally with powerful shallow-draft tugs and barges. The tow-boats (which actually push, closely coupled to the barge) range from 200-hp shuttle boats to twin-screw, tunnel bottom diesel boats of more than 5,000 hp, but draw less than 7 ft of water. Even with the more powerful towboats, the use of four-barge tows is practicable only approximately 30% of the time because of the swift water and narrow channels. Specially constructed steel barges, usually about 40 ft by from 165 ft to 175 ft are utilized on the upper river. Many of these barges are designed to carry petroleum products upstream as large tankers and to carry wheat downstream as a deck load. These two-way pay loads consist of 290,000 gal of liquid petroleum products or 1,000 tons of wheat. Fig. 4 shows a load of petroleum being transported.

Navigation problems that remained to be solved were the following: The swift currents, in excess of 10 miles per hr through the rapids at medium stages; the insufficient depth and width of the channel during a large part of the year; the narrow, rock-bound channels lined with points on the sides and pinnacles on the bottom; the excessive time required for shuttle passage of barge tows through The Dalles-Celilo Canal; and the shallow water between the main channel and those installations at which the exchange of cargo between land and river takes place. Complete removal of the narrow sections through the many rapids would serve only to lower the intervening pools and would cause additional problems. Restricting the swift water to deeper channels would serve to increase the velocities, which already caused the downstream barge tows to travel at unusually high speed in order to maintain steerage way. Although river improvement would be possible at great expense, the solution of Columbia River and Snake River navigation problems was seen at an early date to rest with locks, dams, and slackwater. The fear, expressed by irrigationists, that open channel navigation would require more water, also indicated a slackwater project.

COLUMBIA RIVER

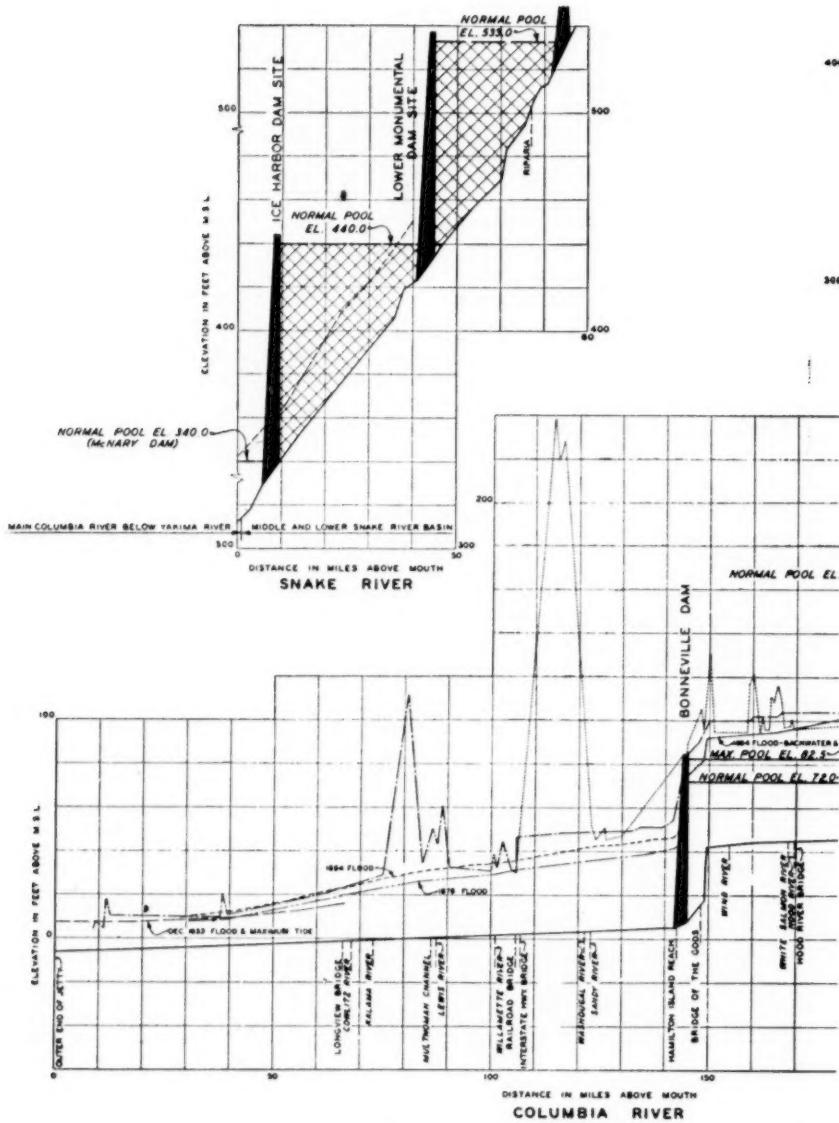
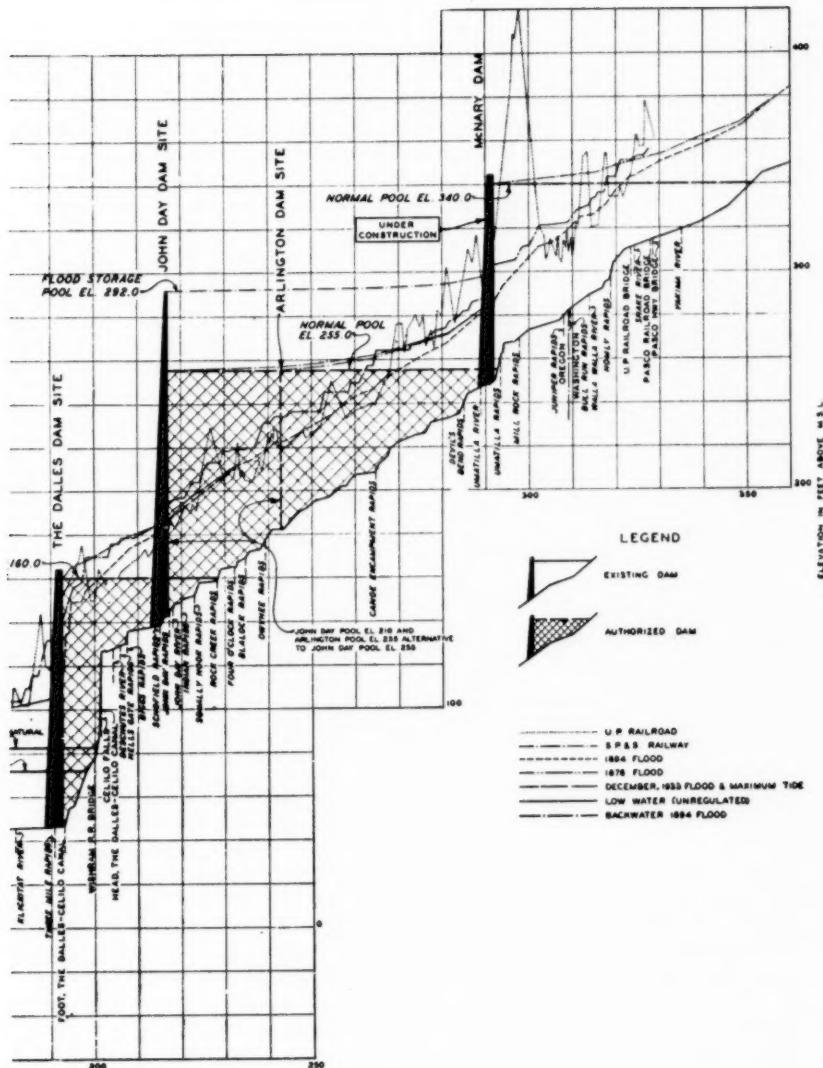


FIG. 3.—PROFILE OF THE COLUMBIA RIVER BELOW THE YAKIMA RIVER.



AND OF THE LOWER SNAKE RIVER, SHOWING MAJOR DAM PROJECTS

The commerce that could hardly support the expense of open river improvement could never be expected to justify the many hundreds of millions of dollars required for locks and dams to provide slackwater over this 275-mile stretch of river from The Dalles to Lewiston with its 650 ft of fall. Even Bonneville Dam, which passed over 1,500,000 tons of commerce in 1952—as compared with the tonnage passed through Cascade Locks or around Cascade Rapids, which never exceeded much over one twentieth that amount in their biggest years—could not be expected to stand on a sound economic footing without the hydroelectric power it generates and for which there is a steady market. Development to serve the joint purposes of naviga-

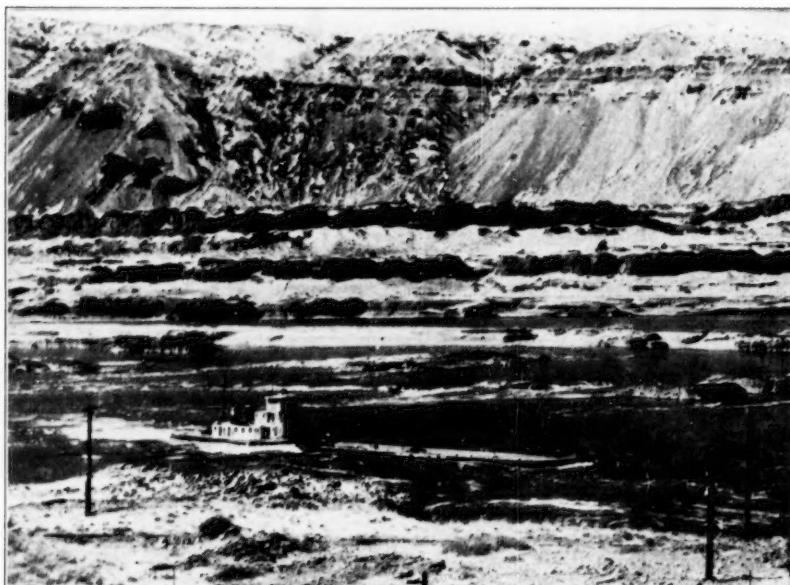


FIG. 4.—BARGE TOW, MIDDLE JOHN DAY RAPIDS, COLUMBIA RIVER

tion and power was a ready solution. The demand for both uses has increased so rapidly since Bonneville Dam was completed that the complete development, considered visionary in 1931, became a justified and fully authorized potentiality less than 20 years later.

After Bonneville Dam was completed, McNary Dam was authorized in 1945 and is now (1953) approximately 70% complete. McNary Dam, located at the foot of Umatilla Rapids, about 2 miles east of Umatilla, Ore., will serve the dual purpose of eliminating the many serious navigation problems in the 45 miles of river below the mouth of Snake River as well as adding a sizeable supply of hydroelectric power from its 980,000-kw installation. In lieu of a controlling depth of 6 ft in a narrow channel through Umatilla Rapids in, which velocities would reach 10 miles per hr, a controlling depth of 9 ft will extend above Kennewick and up Snake River about 10 miles, overlapping the Ice Har-

bor Dam site, the lowest dam of the Snake River series. The McNary Dam pool will be raised to its normal elevation of 340 ft in 1953, the year the first generators will be placed in operation.

In 1945, the Congress of the United States also authorized improvement of the lower Snake River to provide slackwater navigation and power. The most economical plan to develop this 140-mile reach of river with 375 ft of fall, between McNary Dam and Lewiston, consists of a series of four locks and dams, each with from 90 ft to 100 ft of drop and slackwater reservoir pools in between. The projects have been named Ice Harbor, Lower Monumental, Little Goose, and Lower Granite, in upstream order. These projects, in addition to providing slackwater navigation, will also develop power; but, as in the case of the Columbia River projects, they will be run-of-river plants with limited drawdowns for pondage purposes only, which will not interfere with navigation. The initiation of these projects has been delayed because of the alleged possible interference and damage they would cause to the valuable salmon runs that utilize the Snake River and its tributaries for spawning. Funds for the initiation of Ice Harbor are expected to be included in the budget for the fiscal year 1954, and the national defense power schedule for the region calls for its completion with first power on the line in 1957.

The 100 miles of open river between the town of The Dalles and Umatilla Rapids was left, temporarily, without authorized slackwater improvement, although the plans included either two or three dams to close the gap. The most hazardous navigable rapids of the Columbia River will be eliminated by McNary Dam, but others will remain. The most serious bottleneck, the narrow, outmoded The Dalles-Celilo Canal, still remains temporarily at least. In the Corps of Engineers' Columbia River "308" Report,³ dated October, 1948, there was recommended an extensive, coordinated plan of development for the entire basin, including dams at The Dalles and John Day sites for navigation and power to close this gap.³ These were included in a total of seven additional multiple-purpose dams that were proposed as part of the Main Control Plan to meet the present and immediate future needs of the Columbia River basin for navigation, flood control, power, and other water uses. Combined with open river improvements to Lime Point, Idaho, on Snake River, 30 miles above Lewiston, and the previously authorized projects, the Main Control Plan will provide a fully developed channel for inland navigation on the Columbia and Snake rivers from Portland to Lime Point, a distance of 405 miles. In addition, the Main Control Plan will provide positive control of floods equal to the greatest of record on the lower Columbia River, 4,400,000 kw of additional prime power, irrigation for new lands, and many other local, regional, and national benefits. Most of these projects, including The Dalles and John Day dams, were authorized by Congress in the Omnibus River and Harbor and Flood Control Act of 1950 substantially as recommended.

The Dalles Dam, started in December, 1951, at the downstream end of The Dalles-Celilo Canal and just above the town of The Dalles, will raise the water about 88 ft to a normal pool of El. 160. This pool will drown out The Dalles-Celilo Canal, Celilo Falls, and 25 miles of open river to the foot of the John

³ "Columbia River and Tributaries, Northwestern United States," House Document 531, 81st Congress, 2nd Session (8 volumes), U. S. Govt. Printing Office, Washington, D. C., Oct. 1, 1948.

Day Dam. The John Day Dam in turn would cause another 92-ft lift to a normal pool of El. 252 which would extend to McNary Dam, 75 miles upstream. The Dalles Dam was started early in 1951 as a defense measure with funds for 7% completion of the project appropriated to December, 1952. The construction program provides for first power and a full pool for navigation in 1957. Plans have been initiated toward construction of other dams in the basin. Construction is scheduled to begin on Monumental Dam in 1957, on Little Goose Dam in 1958, and on Granite Point and John Day dams in 1959.

What effect on navigation the completion of these individual projects will have is a matter of conjecture. Even more interesting is the problem of forecasting what the river tonnage will be after the completion of all the projects and the necessary terminal facilities and harbors on the pools. Certainly an increase in tonnage can be expected with the completion of each project and a continued and rapid increase in tonnage can be expected after all slackwater improvements are completed and a safe channel maintained at a 9-ft depth with a minimum of 250 ft of width to Lewiston. In addition, the 30-mile open river channel on the Snake River between Lewiston and Lime Point will give an open river channel of 6 ft by 150 ft to tap large deposits of ore and limestone in the vicinity of Lime Point, now isolated from transportation. The advantage of water transportation is the basically lower cost over other means for the movement of large bulk commodities, such as wheat, oil, logs, or lumber. The generally mountainous terrain dividing the various sections of the Columbia River basin and forming a complete closure around the basin, except as cut by the rivers, causes the higher cost of transportation by rail and highway. Because of this situation, and the fact that a large percentage of the production of raw materials and crops are shipped long distances from the basin to market, and a large part of the processed commodities and finished products are shipped long distances into and within the basin, the cost of transportation is a vital problem in the Columbia River basin. In particular, the extensive wheat-producing areas of Montana and the Palouse area of Washington need cheaper transportation to tidewater for coastwise and export trade. Cheaper transportation is needed to deliver logs and lumber to market and cheaper transportation is needed between tidewater and the central parts of the Columbia River basin for a large tonnage of petroleum products. Economical transportation of any sort is needed in getting the ores and other minerals of the lower Snake basin to tidewater and to market. For all of these, the low cost of bulk shipment on a slackwater river is attractive. In estimating the tonnage that would be available for water shipment, careful studies were made of the production and consumption potentialities of the areas contributory to the navigation system. These totals have been discounted to allow for local consumption, and for movement in other directions, or by other transportation means.

For example, 65% of the wheat production was considered to be potential tonnage for barge movement. Generally, 20% of the inland lumber production was estimated to be available for river movement. Limestone and ore, previously inaccessible in the Snake River Canyon, will be moved by water

in quantities determined by the probable future demands indicated by the trend of economic development, and will be influenced also by the depletions of the resources in other sections of the nation which are now in heavy use. Petroleum products, the largest single item to be carried upstream, can be estimated on the basis of per capita consumption (currently determined by authoritative sources to be approximately 1 ton per capita annually) and by means of estimates of future population. It is estimated that 80% of the petroleum products now moving into this interior region moves by river barge. It is difficult to evaluate what net effect the oil pipe line from eastern sources (completed in 1950) will have on this commerce. While it has diverted tonnage that otherwise would have moved by river, there has not been any reduction to date (1953) because of it. Doubtless the large future demands and possible future increases in per capita consumption will bring about further increase in movement of petroleum products.

The results of these studies yield an estimated future average annual commerce for the Columbia River and Snake River slackwater system of nearly 5,000,000 tons, more than three times the 1952 commerce. The transportation savings expected to be realized in this commerce have been estimated at nearly \$7,500,000 annually. Because the transportation system that makes these savings possible assumes a through and uninterrupted artery of commerce, all navigation improvements in the system must be provided to accomplish the system's savings and must share equitably in the total benefits. Accordingly, these benefits can be prorated to the improvements composing the river system by first assigning benefits equal to the annual cost of the single-use navigation improvements and distributing the balance of the benefits among the projects on the basis of ton-miles of commerce transported over the length of river improved by each project. Although the use of the cost of single-purpose navigation facilities only, in this computation, neglects the possible total charges upon final allocation of the total project costs among the uses served, application of this procedure indicated a balance of benefits to distribute in the Columbia River system—actually a benefit-to-cost ratio for system navigation of 2 to 1.

The addition of each individual slackwater pool prior to completion of the system eliminates another stretch of rough, dangerous water. Within this stretch, new water tonnage will originate and terminate, and through tonnage will move faster, more economically and, as a result, in larger amounts.

With the elimination of the Cascade Locks and Cascade Canal, as a result of the completion of Bonneville Dam, a new impetus was given to up-river traffic. The reservoir behind McNary Dam will eliminate several miles of rapids, including two of the most dangerous. Slackwater port facilities will be available at Pasco and Kennewick. Although no appreciable amount of through tonnage up the Snake River can be expected to result until the lower Snake River is slackwatered, the tonnage originating or terminating in the pool may be expected to exceed 500,000 tons annually within a reasonable number of years with no further system additions. This would be approximately half the system potential of the Snake River (the estimated average annual comparable commerce after the system is completed), but it would represent a substantial increase over previous commerce. A larger addition

can be expected with the completion of The Dallas Dam with the elimination of the bottleneck of The Dalles-Celilo Canal. In this case, the principal beneficiary will be through traffic. On the other hand, addition of the Ice Harbor Dam will add some tonnage directly tributary to its own pool, some from seasonal open river operations upstream as far as 100 miles to Lewiston. However, completion of the improvement to Lime Point is necessary to tap heavy tonnage. Each project will make a contribution which will grow and be added to, as another "link in the chain" is completed. By 1970, the Columbia-Snake slackwater system probably will be complete; and before that time, consideration will be given to extending the system up the Columbia River or up the Snake River for the development of additional territory. By that time the Main Control Plan will be effective not only in supporting considerable commerce in slackwater navigation, but also in providing large amounts of electrical energy, and controlling floods on the lower river.

SUMMARY

The slackwater improvement of the Columbia River has been established as definitely the most feasible method of providing safe, efficient, and successful navigation on the Columbia and lower Snake rivers. A comprehensive plan to this end, originally proposed in the early 1930's as a possibility for the distant future, became an authorized reality less than 20 years later. In fact, it is well on the way toward achievement with the completion of Bonneville Dam, with McNary Dam and The Dalles Dam under construction, and with the Ice Harbor project under serious consideration for early initiation. Completion of the first step in this improvement, the opening of the Bonneville Lock in 1938, marked a sharp and even phenomenal increase in navigation tonnage which continued at a high rate for several years before it leveled off. With each additional new increment in the system, added tonnage may be expected. The average annual tonnage of the completed system over the 50 years following completion of the last project by 1970, is estimated at nearly 5,000,000 tons as shown in Fig. 2—five times the tonnage carried into the upper river in 1949 and possibly one-thousand times the average tonnage for the 50 years preceding the completion of Bonneville Dam. Water transportation has been a major factor in the economic and social life of the Columbia River basin. The growth and full development of the region will be as dependent on the adequacy of transportation in the future as it has been in the past, and the part that the Columbia River played in the early economic history of its basin will be followed by a sequel in the future. Railroads and highways also have played an important part in this development and will continue to do so in the future. The problems of early competition between these land forms of transportation and water transportation have been greatly reconciled, and further reconciliation will be achieved in the Columbia basin, as has been done in other more highly-developed areas in the east. In many areas, it has been shown that the growth of navigation has resulted in a comparable growth in the railroads and highways that either parallel or feed the waterways. Water commerce will continue to play an increasingly important part in the development of the United States and will continue in the Columbia River for many years after completion of the slackwater improvement.

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